Current Construction Program Research Goals and Sub goals

Goal 1: Reduce the major risks associated with traumatic injuries and fatalities in construction.

Introduction

The Construction Program has focused a major portion of its efforts on fatalities for a number of reasons: 1) Construction has the largest number of fatal injuries of any sector by far and suffers a disproportionate national share of such deaths; 2) fatal injury rates over the years have wavered and have only recently begun to show a steady decline; 3) Congressional appropriations language over the years has explicitly addressed a concern about fatalities in construction and have directed NIOSH to address this concern; and 4) risk factors for fatal and non-fatal injuries are expected to be similar for some important causes such as falls from height.

Construction Program injury research has focused on top fatal injury events and exposures in the industry such as: falls to lower levels (35% of fatal construction injuries); struck by objects (12.1%); contact with electric current (9.8%); pedestrian struck by vehicle (6.3%); and caught in or crushed by collapsing materials (5.7%) [BLS, 2004]. Most Program efforts begin with analytic injury epidemiology to identify key risk factors underlying injury patterns. In most cases, fatal injury investigation is the most available source of information for this work. Non-fatal injuries are also an important problem in construction, and injury researchers have used a variety of sources, from emergency room data to workers compensation reports, to identify non-injury risk factors and patterns.

Construction injury prevention is an area where OSHA has a number of important regulations. Program researchers have identified important gaps in regulations along with new technologies and work practices needing special consideration. We have worked with partners to develop interventions and guidance to address these issues. Examples of issues include communication tower erection and usage of aerial lifts. We have used engineering knowledge to develop or improve interventions such as detection of overhead power lines or fit of safety harnesses. In other cases, we work to help raise awareness of risk factors or help develop training materials to address familiar but important problem areas such as trench safety, ladder safety, and electrical safety.

Reference

U.S Bureau of Labor Statistics.[2004] Percentages derived from 2004 BLS data available by industry sector for event and exposure at http://stats.bls.gov/iif/oshwc/cfoi/cftb0204.pdf

Sub-goal 1.1 Falls from Elevation

A) Issue

Falls are the largest single source of fatal injuries for construction workers accounting for 33% of total construction fatalities in 2005. Construction experiences a disproportionate share of fall fatalities. While construction represents about 7% of all workers, construction workers experienced 52% (394) of the 770 fall fatalities that occurred across all industries in 2005 [BLS, 2005c].

Occupations with high frequencies of fatal falls include ironworkers, roofers, and laborers (approximately 68, 26, and 10 deaths per 100,000 FTEs per year respectively). The average fatal fall rate for all construction occupations is about 4 per 100,000 FTEs [CPWR 2002]. In 1997, the major types of falls were falls from structures (roofs - 34% and structural steel – 9%), from scaffolds (17%), from ladders (17%), and from aerial lifts (5%) [McCann & Chowdhury 2000].

Falls were identified by labor and management stakeholders as a top construction problem at the 1993 National Conference on Ergonomics, Safety, and Health in Construction that helped initiate the NIOSH Construction Program. That conference included a recommendation that new approaches to regulation such as negotiated rulemaking were needed, and this led to a 1994 negotiated rulemaking on fall protection during steel erection. The final rule was issued in 2001.

B) Activities

Construction Program researchers conducted a number of surveillance and investigation studies about fall injuries and fatalities, often learning where to focus prevention efforts in the process. We conducted surveillance activities, intervention research, and training and dissemination efforts related to falls involving roofs, structural steel, scaffolds, ladders, and aerial lifts. We also conducted activities related to telecommunication tower construction and construction vehicles.

Surveillance and investigations

Structures and Roofs -- Construction Program researchers found that in 2004, falls from roofs killed 178 workers and constituted the leading cause for work-related fatalities in the construction industry [BLS 2005]. Falls from roofs are also a major cause of serious nonfatal injuries in the construction industry. In 2004, 2,220 workers were seriously injured after falling from roofs [BLS 2006]. Construction Center researchers looked at fall deaths in the structural steel industry for 1992-99 and found that 21 of 116 (18%) were falls from metal decking [Paine & McCann 2004]

Scaffolds -- Each year, more than 60 workers are killed by falls from scaffolds, about 1 in 5 of the fatal falls in construction. Of these, about 10 deaths per year are from suspension scaffolds, and the rest mostly supported scaffolds. We found that for supported scaffolds, the main causes of injuries and deaths are problems with planks and guardrails, poor planning for assembling and taking them apart, missing tie-ins or bracing, loads that are too heavy, and being too close to power lines.

A Construction Center research team that included a former scaffold erector used a 150-point checklist to survey supported scaffolds at 113 construction sites in nine geographic areas of the eastern United States. About 32% of the scaffolds were either in danger of collapse or were missing planking, guardrails, or adequate access in ways that posed an imminent danger to the workers. Strong correlations were also found between proper scaffold safety practice and 1) presence of a competent person who claimed to have scaffold safety practice; 2) scaffolds that were not solely frame scaffolds; and 3) scaffolds having been erected by a separate scaffold erection contractor.

Ladders -- Ladders are widely used throughout construction, and falls from ladders are the third leading cause of deaths from falls in construction [CPWR 2002]. Construction Program researchers reviewed data systems such as FACE, CFOI, and data from the Kentucky Employers Mutual Insurance Company and the Maine Department of Labor to identify contributing factors to ladder falls. [McCann 2004a, 2000; McCann et al. 2003].

Construction Program researchers studied the leading causes of falls involving extension ladders [Hsiao et al. 2006]. Construction Center researchers from Harvard University School of Public Health and Liberty Mutual Insurance Company are expanding research on extension ladders to other ladders. They are looking at ladder-related fracture injuries to determine if and how ladder fall fractures differ from other ladder-related injuries.

Aerial Lifts -- Program researchers found that the number of fatalities related to aerial lifts is showing an increasing trend: from 19 deaths in 1992 to 38 deaths in 2003. [Pan et al 2005] Contributing factors included mechanical failure and work practices.

Telecommunications towers -- Construction Program researchers reviewed Bureau of Labor Statistics and Occupational Safety and Health Administration (OSHA) data systems to identify and characterize fatal injuries incurred by workers constructing or maintaining telecommunication towers for the years 1992 through 2005. In addition, Construction Program and Construction Center researchers investigated 10 incidents involving 12 telecommunication tower-related fall fatalities from the years 1992 through 2001. Investigations of these fatal events revealed several important causal factors: failure to use or the improper use of personal protective fall equipment, use of improper or

inadequate hoisting equipment, lack of maintenance of hoisting equipment, lack of employer safety and health programs, and lack of structured training.

Vehicles -- Current statistical systems count injuries occurring to workers delivering materials to construction sites as construction injuries. We found that in 2005, BLS data showed 2,030 non-fatal falls from non-moving construction vehicles involving days away from work [BLS 2005b], as well as, 18 fatalities [BLS 2005c]. The causes of these falls can include slips and trips, poor vehicle entrance design, and poor design of ladders and other means of access to the truck vehicle body.

Intervention development/evaluation

Structures, roofs and scaffolds -- The Construction Program work in this area over the past decade includes:

- developing an adjustable roof guardrail assembly that can accommodate various roof pitches to protect residential construction workers from falling to lower levels;
- evaluating and disseminating Leading Edge Fall Protection Systems to protect iron workers from falls during decking operations,
- evaluating and disseminating a fall hazard audit system to improve recognition and control of fall hazards over a construction project,
- validating virtual reality technologies for fall-from-roof prevention research;
- identifying the effects of visual cues on balance control during roofing work;
- modifying fall protection harnesses to improve fit and decrease the physiologic impact to the wearer when suspended

- developing improved footwear designs for work on roofs; and,

- establishing sensory-enhancing technology to improve workers' balance on roofs.

Construction Center researchers evaluated a Leading Edge Fall Protection System for ironworkers installing decking inside a controlled access zone. [Paine & McCann, 2004] The evaluation involved: 1) documentation of the training of ironworkers in this new fall protection system; 2) documentation of the installation of this fall protection system; and 3) documentation of the use of this fall protection system. Six steel erection sites in Connecticut, Rhode Island, and Massachusetts were used. During site visits, there was 100% compliance with use of fall protection. At these sites, 29.6 FTEs used this fall protection system. According to the employer's records, they had six "saves", where the fall protection system prevented injuries, a rate of "saves" of 20.3 per 100 FTEs. However, there were two falls during installation of the system. The evaluation demonstrated that it is possible to provide effective fall protection during metal decking in structural steel erection. It also showed that it is important to ensure that fall protection is used during system installation.

In 1995, the Construction Center funded the West Virginia University (WVU) Fall-Safe Program, which assists participating contractors in the West Virginia area in the development of a fall health and safety program and audits them [Becker et al. 2001a]. Sixty-five construction companies participated in the program. Results of a program evaluation study showed that the intervention contractors increased the control of fall hazards from baseline by 17% over a year and a half period. The control group of contractors increased the control of fall hazards 0.6% over the same time period. The implementation of fall hazard program management elements increased 30% in the intervention group, while the control group decreased the program management implementation by 7.5%.

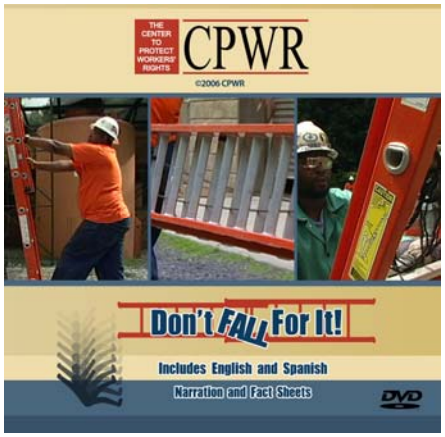
Ladders – Based on interviews with workers, investigators created a practical training intervention in the form of two sets of simply-worded guidelines, each grouped into manageable numbers of tasks and subtasks [Lineberry et al. 2002].[1] The checklists have been tested with small Kentucky contractors and at the 2002 Construction Safety Conference.

The Program developed a simulation training exercise for ladder safety that seeks to go beyond prescriptive safety training to enhance skills and awareness about issues such as integrating safety with production demands [Wiehagen et al. 2002]. The CSL exercise involves participatory small group problem-solving by working through simulated steps in setting up a ladder for a steel erection welding job.[1]

Construction Program and Center researchers, along with the University of Kentucky, developed a fall hazard recognition program based on viewing and

discussing stereophotographs (Viewmaster disks) of construction sites in small groups. [Scharf et al. 2007]. The CSL exercise and fall hazard recognition training program were evaluated with apprenticeship trainers from the Northern New Jersey Iron Workers Training Program in 2003. Their District Council has adopted their use.

Construction Center researchers developed a pilot program entitled, “Campaign for Reducing Construction Worker Fatalities.”[1] The project developed and pilot tested a “Don’t Fall for It” Ladder Intervention, an 11-minute film with four fact sheets. We pilot-tested the materials among 461 apprentice and journey-level union construction workers in 2006, both directly on job-sites and at union training centers. Results from a pre-test post test survey showed significant changes in self-reported knowledge, attitudes and behavior [Gittleman 2006]. Faculty and students at the George Washington University School of Public Health, conducted a social marketing assessment of the program among small construction contractors to provide additional insights to researchers.



Aerial lifts -- We analyzed at least 150 litigated cases involving cranes and aerial lifts and identified fifteen significant failure modes that cause injury and death.[MacCollum 2007].

Program researchers are testing two scissor lifts obtained via letter of agreement with a leading scissors lift manufacturer to examine stability under a range of loads and at various heights.

Telecommunications towers -- In 1996, in an effort to combat the high number of fatalities of their membership, and to gain consistent inspection procedures and regulation interpretations, the National Association of Tower Erectors (NATE) approached OSHA to develop such procedures. As a result, the OSHA Telecommunication Tower Task Force was formed in April 1997.[1] Program researchers participated.

Vehicles -- In 2001, at the request of the International Brotherhood of Teamsters, Construction Center researchers undertook studies of hazards facing Ready Mixed Concrete truck drivers [Clark et al. 2001, McCann 2006]. We used focus groups of Teamster Ready Mixed drivers to understand potential slip and trip hazards around construction equipment, and to discuss recommendations for correcting each of the identified problems.

C) Outputs and Transfer

Construction Program researchers authored a total of 29 peer reviewed journal articles on this topic, provided 99 presentations, and developed 32 NIOSH and Center publications, as well as 163 miscellaneous documents such as FACE reports, patents, and book chapters. A comprehensive listing of outputs can be found in Appendix 1.1.

Roofs -- Guardrail assembly -- The Construction Program held a public meeting in 2004 to transfer the guardrail assembly invention into practice. A utility patent application for it was filed in 2005.[1]

Virtual reality technology -- The Construction Program, published the validation studies for the surround-screen virtual reality (SSVR) system, the first SSVR system in the world designed for occupational fall prevention research. The system is currently used to evaluate human performance at elevation, identify risk factors leading to fall incidents, and assess new fall prevention strategies.

Scientists, safety professionals, and construction trade representatives from around the world have visited the SSVR facility and consulted with Construction Program researchers on the application of this emerging and advanced technology to occupational safety research.

Visual cues' effect on balance control -- Construction Program publications in *Injury Prevention* and *Human Factors* journals have shown that at elevated environments, vertical visual anchors within 15 feet of a person's eyes can significantly reduce postural destabilization. The findings have practical implications for improving workers' safety during roofing work. Temporarily, roof guardrails can serve not only as physical barriers to protect workers from falling, but also as visual anchors to reduce workers' postural instability at elevation.

Fall protection harness sizing -- The research report on current harness-sizing issues and the effect of thigh strap angle and back D-ring location as additional harness static-fit-test criteria to enhance post-fall harness fit was published in the journal *Ergonomics* in 2003. The research received the International Ergonomics Association (IEA) Liberty Mutual Prize in Occupational Safety and Ergonomics in 2002. The information in the article is useful to construction employers and workers to ensure selection of the right size and proper donning of harnesses.

Findings from the human physiology study regarding the use of intervention technology to reduce suspension trauma potentials was presented at the American Industrial Hygiene Conference and Exposition in 2006, as was a provisional patent application. The information will be shared with harness manufacturers along with the harness-sizing research results for the new generation harness design.

A provisional sizing scheme with an algorithm that describes the human torso shape-and-size distribution and a set of recommendations for producing vest-type harnesses has been accepted for publication by the *Human Factors* journal. A simplified version of the provisional sizing schedule was presented at the Ergonomics Society Conference and also published in Contemporary Ergonomics in 2005.

The draft report of a second provisional sizing scheme has also been shared with MSA and DBI-SALA.

Footwear for work at roof -- The Construction Program used virtual reality technology to evaluate the effects of different styles of footwear on workers' instability at elevation and has reported results to the safety scientific community.

Sensory-enhancing technology to improve workers' balance -- Construction Program researchers, in collaboration with researchers from Boston University, built and tested a prototype randomly vibrating ("smart") shoe insert to improve workers' balance at elevation.
The smart-shoe insert increases the pressure-sensitivity under the feet by inducing below-sensory-threshold mechanical vibrations.

Structures - Leading edge fall protection system -- In 2006, a 13-minute videotape/DVD, "A Leading Edge Fall Protection System for Metal Decking", was produced to disseminate information to steel erection contractors on how to install and use the leading edge fall protection system. A workbook to accompany the DVD is in production. The DVD has been demonstrated to several target groups, including the NYC Ironworkers District Council, a meeting of The Association of Union Constructors, the Boston-based Construction Institute, and the 17th Annual Construction Safety and Health Conference.

Fall-Safe program -- In 1999, WVU expanded Fall-Safe beyond West Virginia with the partnership of the Chicago-based Construction Safety Council and St. Paul Insurance Company. These organizations performed the same third party validation that WVU does.

Scaffolds -- Construction Center field research on scaffolds produced a 150-point scaffold checklist using a simple four-factor inspection method [Halperin & McCann 2004]. Construction Center researchers have targeted construction and academic audiences, e.g., a presentation to the International Masonry Institute

Training Center in 2004 [McCann 2004b], and at the Annual Construction Safety Conference in 2002 [McCann 2002].

Ladders -- Our study of the surveillance sources including the NEISS was published as a journal article entitled: “Work-related ladder fall fractures: Identification and diagnosis validation using narrative text.”

Program researchers delivered six presentations on the Construction Site Ladder exercise at construction safety meetings. Seven presentations have been made on the extension ladder checklists, including one at the 12th Annual Construction Safety & Health Conference & Exposition, Rosemont, IL in 2002. Seven presentations have been made about ladder safety and the “Don’t Fall for It” campaign to audiences such as the OSHA 500 Master Instructor Meeting in Silver Spring, Maryland in October of 2006, and the Liberty Mutual Construction Safety Roundtable in Boston, Massachusetts in November of 2006.

Eight publications have been developed for the various ladder projects, including four fact sheets to accompany the “Don’t Fall for It” DVD and a hazard alert on ladder safety. Over 9,000 copies of the ladder hazard alert have been distributed since 2000, and over 2,200 copies of the “Don’t Fall for It” DVD have been distributed in the first year.

Aerial Lifts -- Construction Program and Center researchers delivered nine presentations at various construction safety meetings to report on findings, including two at the first Aerial Platform Safety Conference in 2004. The “Aerial Lift Safety in Construction” materials from the 2002 Construction Safety Conference presentation are available on the eLCOSH website in English and Spanish.

The Program produced seven publications, including five directed to construction audiences such as the 2005 article, “Falls from Aerial Lifts Raise Growing Concern” published in *Lift and Access Magazine* [Weeks & McCann 2005] and the Hazard Alert on Aerial Lifts (4,794 English copies and 1,271 Spanish copies distributed).

Telecommunication towers -- Construction Program researchers participated in Telecommunication Task Force efforts and provided input to the preparation and dissemination of several important directives and publications.

NIOSH researchers developed and disseminated the NIOSH Alert—“Preventing Injuries and Deaths from Falls During Construction and Maintenance of Telecommunication Towers,” DHHS (NIOSH) Pub. No. 2001-1561. This Alert is now being reprinted in Spanish.

Additionally, 10 FACE reports were published from telecommunication tower-related investigations and widely disseminated through NATE conferences and

OSHA training classes. These reports are available on the Web at: http://www.cdc.gov/niosh/face/default.html. Construction Program researchers also authored two articles ("NIOSH—A Resource for Occupational Health and Safety Support" and "Falls- A Deadly Hazard for Tower Workers") in the October 1998 and March 1999 issues of the NATE monthly publication *Tower Times.* NATE also provides a direct link to the NIOSH homepage and to relevant NIOSH publications in *Tower Times* (http://www.natehome.com/TowerTimes/Index.cfm).

Vehicles – Fall hazard recommendations were described in the publication, *Ready Mixed Concrete Truck Drivers: Work-Related Hazards and Recommendations for Controls* [Clark et al. 2001].

A Partnership has been developed with the National Ready Mixed Concrete Association (NRMCA) and the Construction Safety Director for the Teamsters. This partnership led to an invitation to a Construction Center researcher to attend the 2003 National Ready Mixed Concrete Association (NRMCA) safety conference, held in Denver, Colorado, which opened the door to continued discussions regarding truck design with truck manufacturers.

Two publications from the Program highlighted the significant role of vehicles or heavy equipment in falls-from-height incidents at the Denver International Airport construction site [Lipscomb et al. 2003, 2004].

In a book published as a result of a small grant from the Construction Center, the problem of falls from railroad and other construction-related equipment on railroad spurs dedicated to construction projects was addressed [MacCollum 2007].

D) Intermediate Outcomes

Roofs -- Guardrail assembly -- Four companies responded to a program announcement in the Federal Business Opportunities publication. Construction Program researchers sent the prototype guardrail assembly to all four companies. After reviewing the prototype, two companies—Garlock Equipment Company and Hug One, LLC—expressed interest in producing and marketing the invention. These companies are currently conducting product development and cost analyses, and evaluating potential agreements with the Construction Program to carry forward this manufacturing and marketing venture.

Fall protection harness sizing -- Mine Safety Appliances Co. (MSA) and DBI-SALA Fall Protection Inc. are currently developing prototype harnesses that incorporate the Construction Program suggested sizing scheme. Mine Safety Appliances Co. also has indicated interest in more extensive efforts to develop next-generation harness designs and prototypes using the criteria and schemes identified by the Construction Program. Both MSA and DBI-SALA also responded to a Construction Program announcement in the Federal Business Opportunities

in 2003 for partnership in harness-sizing studies and in transferring the knowledge to design and commercialization. Since the two manufacturers account for about 60 percent of the national market share of fall-arrest harnesses, the future adoption potential of the new harnesses and sizing systems in the construction trades is very high.

Virtual reality technologies -- Staff members from the Finnish Institute of Health and the Japan Occupational Health University have expressed interest in adopting the Construction Program SSVR concept as a technological foundation on which to develop their fall prevention research laboratories.

Structures - Leading Edge Fall Protection System -- Several contractors at The Construction Institute meeting and The Association of Union Constructors meeting expressed interest in the system and the DVD. See "What's ahead" section for additional information on this ongoing project.

Fall-Safe program -- St. Paul Insurance company implemented the Fall-Safe program with 24 of their construction company accounts in the Mid-West region and Construction Safety Council provided and implemented the program with 16 Chicago-area construction companies. The audit tool concept using a PDA resulted in an ongoing technology transfer process to transform the audit tool into a commercially available audit tool for use by the construction industry and research communities. It has been expanded into other hazard areas and has the ability to collect data without geographic limitation through a web portal and to analyze all of this data collectively. The success of this software has also allowed other researchers to use a PDA based audit tool to collect field data.

Scaffolds -- The Chicago-based Construction Safety Council is incorporating Construction Program findings in worker training and scaffold competent-person training materials, e.g., six, interactive, web-based training modules for OSHA.

In addition, Construction Center researcher Michael McCann was appointed in 2006 to the New York City Suspended Scaffold Worker Safety Task Force, which was formed by the Mayor in response to a series of scaffolding fatalities. The Task Force produced a study titled "Steps to Safety: Recommendations for improving the safety of workers on suspended scaffolds" [NYCDOB 2006], and its recommendations were implemented by the Mayor in 2007. Three companion safety bills represent additional outcomes from the Task Force: 1) Introductory Number 522, requiring that all suspended scaffolds be inspected daily, and that a record of the inspection at the job site be made available to Buildings Department personnel; 2) Introductory Number 523, requiring any person using or installing a suspended scaffold hung from a C-hook or outrigger beam to notify the Department of Buildings at least 24 but no more than 48 hours prior to the start of their use or installation; and 3) Introductory Number 524-A, setting forth an increased penalty schedule for non-compliance with the regulations governing licensed riggers and others who supervise suspended scaffolds.

Ladders -- While the extension ladder checklists are still undergoing evaluation, the construction partners involved with the preliminary evaluation[1] have continued to use the ladder setup and use checklists.

"Don't Fall for It" DVD and fact sheets are being used by a number of individuals and organizations. For example:

-The Construction Institute, Boston Massachusetts is using the DVD throughout the MA Building Trades apprenticeship and training program.
-The Occupational Health Program at the Massachusetts Department of Public Health is assessing the program in the vocational technical school system. They have also shared it with a Massachusetts interagency group on fall prevention.
-The Liberty Mutual Construction Safety Roundtable distributed copies of the program to 75 contractors.

The Hazard Alert on ladders developed by Construction Center researchers has also been reproduced and presented in both union and peer print media, including. *The Boilermaker Reporter (*International Brotherhood of Boilermakers) and *Contractor Tools and Supplies* .

Aerial lifts -- The partnership formed in 2004 between the Construction Program and SkyJack, Inc. involves an agreement to jointly develop alternative aerial lift designs and safer work practices to reduce aerial lifts-related injuries and fatalities. The agreement has been the subject of trade press coverage in trade press such as *Lift and Access Magazine* (see the following links for details):

- http://www.liftandaccess.com/index.php?id=295
- http://www.liftandaccess.com/index.php?id=691

A Construction Center researcher is chairing the American National Standards Institute (ANSI) A.10.29 committee for the proposed standard titled: "Safe Practices for the Use of Aerial Platforms in Construction." Balloting of the proposed standard is expected in 2007.

The Program's activities will provide information to other international standards committees. These committees include the ANSI A92 Aerial Platforms Main Committee and various A92 sub-committees, the U.S. Technical Advisory Group to ISO Technical Committee 214 Elevating Work Platforms, and the Canadian Standards Association (CSA) B354 Elevating Work Platforms Technical Committee. Once successful tests are achieved, this joint Construction Program-manufacturer research effort should ensure the commercialization and availability of new safety features on scissor lifts.

Two trade journals have discussed the Program's work on aerial lifts [Anon. 2001, Anon. 2003].

Telecommunications towers -- The Telecommunications Tower Task Force reviewed the leading identified causal factors and, to address these factors, developed and in 1999, issued a compliance directive entitled, "Interim Inspection Procedures During Communication Tower Construction Activities" [OSHA 1999]. To address falls from these towers, which were the leading cause of fatalities, 100 percent fall protection is now required. This means that tower erectors have to use fall protection (being attached to the tower or a safe climbing device) from the time they leave the ground until they return to the ground. The 100 percent fall protection and personnel hoisting requirements contained in the initial and revised directive were supported by Construction Program investigative findings and data input and, when used correctly, decrease worker exposure to fall hazards. In 2002, the compliance directive was revised to remove the restriction that employees' workstations had to be over 200 feet above ground before they could ride hoist lines to the workstations [OSHA 2002].

In 2005, Construction Program data analysis, information from fatality investigations, and recommendations were used in the development of the North Carolina Telecommunication Tower Standard, the first state standard in the nation [NCDOL 2005].

NATE has disseminated more than 8,000 copies of the NIOSH Alert to conference attendees at their annual conference and expositions.

Information from tower-related Construction Program activities was used to develop a safety checklist and a three-day train-the-trainer program for OSHA compliance officers and others, and two safety manuals produced by NATE.

Construction Program researchers also provided the Safety and Environmental Compliance Office of the Federal Aviation Administration (FAA) in Miami with information that led to the successful development of a scope of work involving the retrofitting of a damaged NDB antenna tower at Great Inagua, the Bahamas**.** This information included procedures to identify damaged tower components and procedures to replace these components without causing further damage to the tower or injury to workers. The FAA was also provided NATE and OSHA contacts who could supply additional information on accomplishing repair and replacement operations safely.

The president of wirelessestimator.com developed an article on the use of Construction Program telecommunication tower-related reports as training aids for the wireless industry. Wirelessestimator.com is a free Internet service for the wireless industry. According to this site: "Tower construction industry leaders and safety professionals believe that FACE reports can be used effectively to create

a greater awareness of how fatalities can easily arise and what preventative measures can be taken to keep them from occurring."[1]

Finally, Construction Program researchers provided the Principal Specialist Inspector United Kingdom Health and Safety Executive Technology Division and the Specialist Team Leader United Kingdom Health and Safety Executive Technology Division with safety and health information developed jointly by the Construction Program, OSHA, and NATE pertaining to radio frequency (RF) radiation and working safely at heights. This information was provided through links to NIOSH and OSHA web sites.

Vehicles -- The Ready Mixed document is available directly or through links on:

1) OSHA's web site
http://www.osha.gov/dcsp/products/topics/concreteproducts/industrycontrols.html#const

2) The Illinois Ready Mixed Concrete Association website
http://www.irmca.org/links.php?id=12

3) The New York Committee for Occupational Safety and Health website
http://www.nycosh.org/specific_industries/Transportation/transportation.html

4) The Mt. Sinai Construction Hygiene and Ergonomics Program website
http://www.thechep.org/publications.html

E) External Factors

Roofs -- Multiple factors interactively affect efforts to prevent falls from roofs. Worker training on regulations (e.g., use of guardrails, safety nets, or fall-arrest systems) is the primary focus for preventing falls from roofs. However, many construction activities are exempted from the regulatory requirements for practical reasons (i.e., technology, cost, and operation). In addition, research aimed at preventing falls has been hindered because of the difficulty in accessing work environments and worker activities at elevation (even with management and workforce cooperation) and the potential injury risk to researchers. Also, testing new engineering solutions at elevated construction sites can expose workers to additional fall exposures and risks.

A major external factor in implementing leading edge fall protection is OSHA's Subpart R on structural steel erection, which allows workers installing metal decking inside a controlled decking zone to work without fall protection (29 CFR 1926.760(c)(3)). The rationale had been that standard personal fall protection systems were more hazardous to decking workers than no fall protection. The evaluation of the leading edge fall protection system described above invalidates

this assumption. However, this OSHA exemption is a stumbling block in getting contractors to adopt this system. The major external factor in favor of this leading edge fall protection system is the large number of fatalities associated with decking.

Scaffolding -- Scaffolding collapses can be deadly and can result in multiple fatalities for construction workers. Unlike many other types of construction accidents, they can also affect the general public, and scaffolding collapses frequently are covered by local newspapers and TV. As seen in the recent cases involving New York City, this can serve as an external factor to facilitate addressing safety and health regulatory and practice gaps.

Two major external factors affecting the safe use of scaffolding systems continue to be: 1) the proliferation of scaffolds in large cities like New York; and 2) language barriers. Large scale renovations and new construction means that the ability of enforcement agencies to inspect the multitude of scaffolds is greatly decreased. The use of immigrant labor – usually non-union and non-English speaking – makes training and communication on the job very difficult. In addition there are a wide variety of fly-by-night contractors who hire undocumented aliens, provide little if any safety equipment, and then disappear without paying the workers.

Ladders -- The fast pace and time pressures associated with construction can contribute to “shortcuts” and use of ladders when other equipment such as scaffolds would be more appropriate. OSHA does have a standard for ladders and while it addresses many important design, strength, and ladder set up issues, it offers only partial coverage of issues related to misuse of ladders or the extent to which ladders can be used as work platforms.

Aerial lifts -- The lack of specific OSHA standards on all but Vehicle Mounted Elevating and Rotating Work Platforms (29 CFR 1926.453) is an external factor.

Vehicles – One external factor influencing Ready Mixed truck driver fall safety is the desire and willingness of truck manufacturers to make modifications to their vehicle designs. Another is that the OSHA construction standard does not have requirements for fall protection on vehicles. The definition of walking/working surface in 29 CFR 1926.500(b)(2) for Subpart M specifically excludes vehicles and trailers. In addition, transport systems such as trucks or railroad cars that are used to deliver and deploy construction materials to construction sites are under the jurisdiction of the U.S. Department of Transportation, not OSHA [MacCollum 2007].

F) What's Ahead?

Roofs -- During 2007, guides will be developed to explain visual anchors to contractors and workers, and to help them select footwear for roofing work. Interactions with a leading work-shoe manufacturer (Iron Age Corp.) and the American Society of Testing Materials (ASTM) International Committee F13 (Safety and Traction for Footwear) will continue to transfer research results.

Research results form the sensory-enhancing device for postural stability will be transferred to the Afferent Corporation to facilitate its further development for application in the occupational safety field.

WVU has attempted to continue the Fall-Safe program with participating contractors in WV as a for-pay program. Thus far, there has been interest from 5 of the original participating contractors. The cost of the complete intensive program may lead to a reduced version of the program for a more practical price for the contractors. This for-pay program will include an expanded hazard emphasis, not just falls, so the contractor can receive the benefits of an intensive management program to reduce the risk of all injury types.

Structures - Leading Edge Fall Protection System. The materials will be piloted in the field using a steel erection contractor not familiar with the materials or approach. The purpose is to insure that the training materials are responsive to worker and contractor questions. The training materials will then be finalized and the materials will be disseminated using a targeted strategy. It includes distribution of the final DVD and accompanying materials through the International Association of Bridge, Structural and Ornamental Iron Workers and the Association of Union Constructors and steel erection trade journals. The DVD will be shown at ironworker and steel erection contractor meetings, and at construction safety and health conferences (e.g., North American Steel Construction Conference, the Annual Construction Safety Conference in Rosedale, IL) as well as professional construction safety conferences (e.g., American Society of Safety Engineers annual meeting. The pilot program results will be published in a peer-reviewed article.

Scaffolds – Mast scaffolding systems are a relatively recent development, and they have been associated with several fatalities. The Construction Center put together a team of interested stakeholders and researchers to examine the adequacy of current regulations, best practices, and training for Mast scaffolding systems. The group includes OSHA, NIOSH, contractors, the International Masonry Institute, manufacturers, the Scaffold Industry Association, and building trades unions.

Telecommunications towers -- In November 2006, OSHA and NATE formally entered into a nationwide partnership agreement. This agreement will require, at a minimum, that companies entering the partnership have a comprehensive

safety and health program, have a competent person as defined by OSHA on each construction site, have all supervisory personnel complete an OSHA 30-hour tower safety course, and have all other workers on site complete an OSHA 10-hour safety course. Partner companies cannot have experienced a fatality within three years that resulted in a serious or willful violation. The Construction Program will continue to provide OSHA and NATE with updated statistics, investigative findings, suggested injury prevention measures, and technical assistance as needed.

Vehicles -- The Construction Center is supporting a small studies grant to The University of Michigan to conduct an ergonomic study on Ready Mixed concrete truck ladders. The purpose is to identify ladder tread and handrail factors that influence grip strength and can affect a person's ability to recover from an incipient fall. Using this data, Construction Center researchers, in conjunction with the Teamsters, intend to go to the truck manufacturers to encourage them to take these ergonomic factors into account in designing their Ready Mixed trucks and make retrofit kits available to owners of existing trucks. There will also be a campaign to convince manufacturers to make up-to-date safety features mandatory on new trucks, not optional as they are in many instances. Awareness materials will also be developed for Ready Mixed concrete truck drivers.

NIOSH developed a strategic goal for falls as part of its 2005 strategic goal development process. The draft goal included various intermediate goals to inventory current fall protection practices and to fill gaps where technical approaches either need to be developed in the first place or need modification to be more cost-effective for smaller employers. It also included draft intermediate goals to address implementation issues – such as expanding the use of safe by design practices via demonstration projects and evaluation of the impact of construction procurement practices on the implementation of fall protection. It included addressing disproportionate risks to Hispanic construction workers by identifying and addressing unique underlying causes and it suggested working with construction partners to develop and implement a national campaign to reduce fatal and severe injuries associated with falls to a lower level. The topic of falls was also selected as top traumatic injury problem by the NORA Construction Sector Council and is undergoing additional discussion as part of developing a national construction agenda

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Appendix 1.1

Outputs -- Falls from Structures

Surveillance and Risk factor identification

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Outputs -- Scaffolds

Surveillance and Risk factor identification

Journal articles

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Outputs -- Ladders

Surveillance and Risk factor identification

Journal articles

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Outputs -- Aerial Lifts

Surveillance and Risk factor identification

Journal articles

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Outputs -- Towers

Surveillance and Risk factor identification

NIOSH and CPWR Publications

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Outputs -- Elevators

Surveillance and Risk factor identification

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Outputs -- Vehicles

Surveillance and Risk factor identification

Journal articles

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Intervention development/evaluation

NIOSH and CPWR Publications

Clark N, Dropkin J and Kaplan L [2001] *Ready Mixed Concrete Truck Drivers: Work-Related Hazards and Recommendations for Controls.* Silver Spring, MD: CPWR. September.

Conference Papers and Presentations

Clark N, Dropkin J and Kaplan L [2001] Ready Mixed Concrete Truck Drivers: Work-Related Hazards and Recommendations for Controls. Silver Spring, MD: CPWR. September.

Additional Outputs

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Sub goal 1.2 Contact with Electricity

A) Issue

During the ten year period from 1992-2002 the overall total of deaths associated with contact with electricity was nearly 3,400, with 47% of these occurring in the construction industry [Cawley 2006]. About 1 in 8 construction industry deaths involved electricity versus 1 in 20 for all industry. Deaths and injuries due to contact with electricity are not just a problem for electricians – surveillance data show that it is an important injury risk for many construction trades such as roofers, painters, laborers, operating engineers, and carpenters.

Initial interest in construction electrical hazards pre-dates the creation of the NIOSH Construction Program. The FACE program investigated 224 electrocution incidents involving 244 fatalities from 1982 through 1994. The resulting information was used to develop seven NIOSH Alerts directly relevant to electrical hazards in construction work as well as a monograph summarizing the FACE electrocution investigations[1]. These findings were also used by OSHA to update their electrical regulations during this period. Construction Program researchers continue to use FACE investigations to gather risk factor information [NIOSH 1996, 1998, 1999, 2003, 2005]. The Construction Program has built upon these foundations to focus its research to address specific risk factors and intervention needs related to the leading causes of electrical deaths and injuries.

The Construction Program has also supported research to examine and understand important causes of non-fatal injury, such as electric arcing injuries.

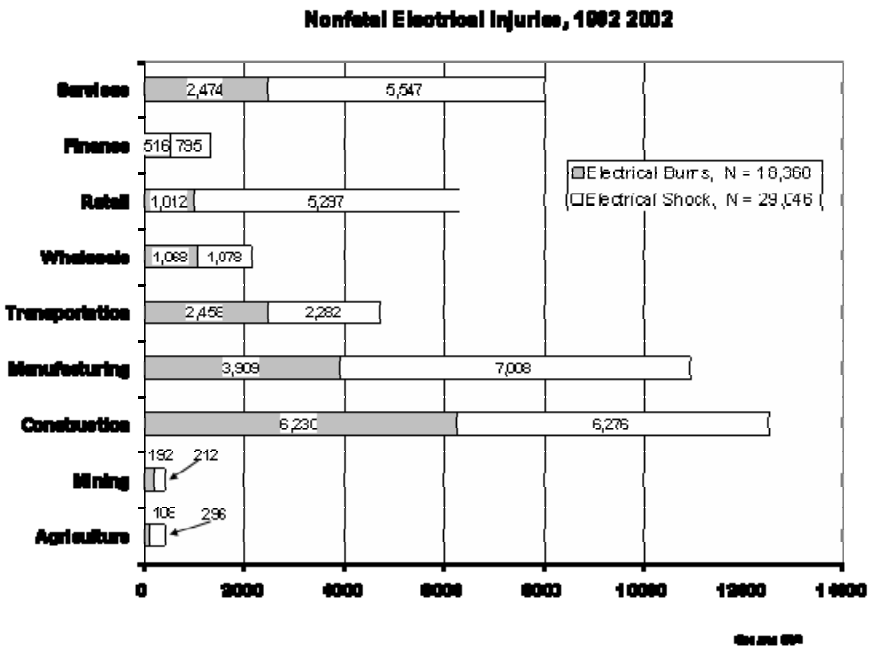


Table 1: Nonfatal Electrical Injuries, 1992-2002

B) Activities

Surveillance

Contact with overhead power lines (OHPL) is the leading cause of construction worker death associated with electricity. Between 1992 and 2002, this cause was responsible for 740 deaths, representing 47% of 1,585 construction electrical deaths [Cawley 2006]. Contact with OHPL may occur during electrical work (installation, maintenance, or repair), when operating or working near high-reaching mobile equipment and machinery, to workers carrying hand held objects such as ladders, tools, or construction materials, or by incidental contact during a non-electrical work activity. Contact with OHPL occurs most often to construction laborers (20% of 740 cases), electricians (13%), electrical power installers and repairers (8%), painters (7%), and roofers and carpenters (each with 6%). Of 89 water well driller fatalities between 1992 and 2002, 28 were electrocutions.

Contact with wiring, transformers, or other electrical components is the second most common fatal electrical event (487 cases - 31%). Contact with the electric current of machines, tools, appliances, or light fixtures, is the third major category of fatal electrical injury (163 cases - 10%).

Intervention development

OHPL

Construction Program researchers analyzed power line accidents involving mobile equipment and concluded that many injured workers had contacted the equipment and ground simultaneously after a power line contact had occurred and were unaware of the shock hazard. These workers could have avoided injury had they simply known after the fact that the equipment had become energized. An overhead power line contact alarm, while not designed to avoid all related injuries is a reliable, affordable, and practical alternative to proximity warning systems [Sacks, et al. 2001]. A contact alarm system was developed and tested for a mobile crane that warns workers when a piece of mobile equipment becomes energized by a power line. Several key finding were that: metal vehicle chassis are equipotential surfaces with variations of only a few volts over their surfaces;[1] road surface resistivity varies greatly,[1] and; electric field detection is not affected by road surface resistivity. The current sensing alarm performed well, except on asphalt road surfaces. A second embodiment detected the increased electric field to ground that occurred between the machine frame and ground after a power line contact and worked satisfactorily on all road surfaces tested. Of the two methods studied, it is the detection method of choice for a power line contact alarm.

Construction Program researchers are evaluating the performance of OHPL proximity warning alarm devices on mobile cranes. The test protocol for the evaluation was developed in conjunction with a number of partners including the International Union of Operating Engineers (IUOE), CPWR, OSHA, Zachry Construction Corp., Allied Safety Systems, Inc. (manufacturer of Sigalarm), Allied

Safety Engineering, Inc. (OHPL alarm manufacturer), and the Association of Equipment Manufacturers. Full scale electrical tests were executed using a mobile crane outfitted with the OHPL alarm devices from two manufacturers. The tests quantified the distance from a power line that each alarm device sounded a warning in various crane - power line configurations. A test report is pending.

In 2002, Construction Center researchers worked with the Hazard Information Foundation Inc. to develop historical and current data on power line contact by cranes and other boomed equipment. The focus of this investigation was to identify the reasons why existing safety requirements are not effective by looking beyond the behavior of the victim, job site operating personnel, and the immediate employer. The study [Hazard Information Foundation 2002] identified opportunities missed by the management of contributing organizations to perform detailed safety planning and secure the worksite against power line hazards before the work crew and equipment arrived for the job. The study compiled hazard control data from a variety of sources to list reasonable, enforceable safeguards and guidelines for safe crane and boomed equipment operation. These proposed safeguards included power line hazard mitigation training for building architects and engineers, contractors, and construction managers.

Construction Center researchers developed an overhead power line training course. This popular course filled a gap hazard recognition and mitigation training in the construction industry.

Contact with wiring and electrical components

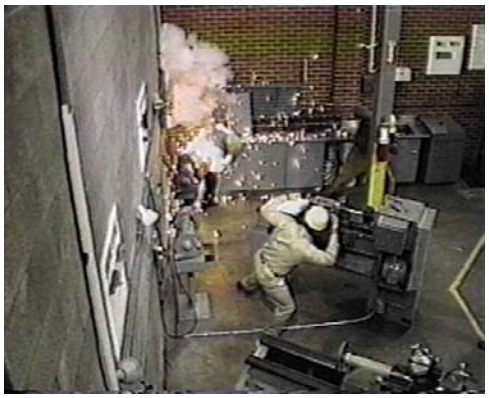
Construction Center researchers collaborated to evaluate a construction project in Washington, DC that was undergoing regular electrical safety inspections by a site safety consultant. Construction Center researchers analyzed these inspection reports. Electrical hazards comprised 17% of the 1,782 hazards identified during 66 site inspections. The main electrical hazards found were extension/power cord hazards (e.g., damaged insulation or cords) and temporary power hazards (e.g., missing light bulbs/cages, exposed live wires). Analysis showed that 12% of electrical hazards were abated the same day, 53% within one day, and 88% within 3 days. This unpublished investigation demonstrated that safety inspections with careful follow-up can reduce the number of and exposure to electrical hazards on a construction site. A follow-on study will determine whether a trained electrician, using a PDA checklist, can effectively conduct electrical safety site inspections.

Construction Center researchers conducted a survey of live work practices among 5,000 International Brotherhood of Electrical Workers (IBEW) electricians. Failure to lock out or tag out electrical equipment before beginning to work is a major cause of construction electrocutions. Three-quarters of the respondents indicated that they had worked on energized circuits in the last month. About half

of employers had a written electrical safety program for working on live circuits. Results showed that more safety precautions were taken when the employer had a written safety program for working live [McCann 2003].

Since workers with less than one year of work experience sustained 30% of all workplace injuries, and since younger workers are at high risk for electrocution, Construction Program staff in 2001 designed electrical safety curriculum for high school and trade school students.

Many electrical hazard interventions are cross-cutting, in that one intervention may successfully meet the needs of several industries. One crosscutting training intervention from the Mining Program with application in the construction industry is a DVD-based training program and an accompanying instructor's discussion guide entitled, "Arc Flash Awareness" [NIOSH 2006].



This training course consists of interviews with three electricians from IBEW Local Union No. 5 who survived serious electrical arcing accidents and the head of DuPont's corporate electrical safety program. The DVD is intended to stimulate viewer interest to learn more about available protections from electrical arcing injury. Although just published, there is widespread construction, petrochemical, and mining company interest in this material.

C) Outputs and Transfer

OHPL
The Construction Program has produced four journal articles, six NIOSH or CPWR publications, three conference presentations, and a patent application related to OHPL safety. Staff have collaborated on additional outputs as part of the transfer of knowledge process.

Construction Program staff were awarded a patent for an OHPL contact alarm system that measures currents that flow though a mobile machine to ground after power line contact occurs [Sacks et al. 2003].

Construction Program staff published an article in the *Water Well Journal* in 2005 that warned of electrical contact hazards. Specifically this article warned water well contractors about the hazard of water well drill rigs contacting overhead power lines and gave seven recommendations for preventing electric shock or electrocution from OHPL. In addition, they warned of hazards associated with working with electrical circuits, such as wiring electric pumps, and recommended precautions to take when repairing or constructing systems involving electrical circuits [Homce et al. 2005].

Construction Center researchers produced the power line safety video"Power Line Hazard Awareness". More than 11,000 copies of the training course were distributed to over 1,700 contractors, contractor groups, unions, companies, municipalities, and associations. The Construction Safety Council estimates that "tens of thousands" of workers have been trained using this course since 1995. [Construction Safety Council, 1996].

In 2006, the Water Systems Council published a revised *Water Systems Handbook* comprised of seven booklets. The handbook is used by the water well industry as one of its principal guideline documents. Construction Program researchers collaborated in the writing of a new section related to electrical safety, based upon their OHPL hazard research [Water Systems Council 2006].

Program staff and activities were the sources of information for an article about OHPL and arc flash hazards in *Occupational Health & Safety* [Laws 2004].

The 2004 *Grey House Safety & Security Directory* (formerly the *A.M. Best's Safety & Security Directory*) cited a Construction Program article in Chapter 4—Electrical Safety, one its training articles authored by personnel from ESFI and DuPont [Clendenin and Grubbe 2004].

Contact with wiring and electrical components
The Construction Program has produced five journal articles, eight NIOSH or Center publications, 17 conference presentations, and an additional publication related to electrical hazards other than OHPL. Some of these outputs may contain information about OHPL safety issues, but overall are more general in focus. A few highlights follow.

A Construction Program study published in the *Journal of Safety Research* entitled, "Occupational electrical injuries in the United States and recommendations for safety research" [Cawley & Homce 2003], was recognized in the Institute of Electrical and Electronics Engineers (IEEE) publication, *Industry Applications Society (IAS) Magazine* as a landmark study with the most comprehensive analysis of occupational electrical injuries ever undertaken [Floyd 2004c].

Program staff worked with the Electrical Safety Foundation International (ESFI) and OSHA to develop a brochure, *"Look Up! Look Down! Look Out!"* The brochure, published by the ESFI, was based on our research and was endorsed by the National Safety Council [ESFI 2004].

More than 54,000 copies of a training text, "Electrical safety: Safety and health for the electrical trades—Student manual" were distributed; another 7,700 copies are backordered [NIOSH 2002]. The text was developed by the Construction Program and is aimed at high school and trade school students. The document is also available for download on the NIOSH web site. The curriculum has been used extensively in trade schools and IBEW apprenticeship training to provide introductory material for students entering the electrical trades. The text received NIOSH's Alice Hamilton award in the educational materials category.

Electrical Construction and Maintenance magazine used electrical hazard FACE reports as the basis for articles in the *Forensic Casebook* section [Anon. 2006a].

American Reconstruction Magazine interviewed the FACE Project Officer regarding storm cleanup [Anon. 2006b].

The IBEW provided a comprehensive overview of the FACE project in the January-February 1993 issue of the *IBEW Journal.*

The Independent Electrical Contractors (IEC) requested a NIOSH Construction Program article on safety issues relevant for electrical contractors and published an article titled: "Update on Electrical Safety Resources" for their May 2007 National Electrical Safety Month edition [NIOSH, 2007]

D) Intermediate Outcomes

OHPL
A Construction Center study was used as evidence in OSHA's 2002 Crane and Derrick Negotiated Rulemaking Advisory Committee that was revising the Crane and Derrick section of Subpart N (1926.550) [Hazard Information Foundation 2002].

Construction Program staff supported development of a strategy by ESFI at an IEEE Industry Applications Society Electrical Safety Workshop in 2004 for the prevention of injuries associated with contact with OHPLs [Floyd 2004b]. Subsequent to that presentation, he was contacted for information regarding his research by a representative of an officer of the ANSI C2-National Electrical Safety Code. He sent them a copy of the Construction Program article published in the *Journal of Safety Research*. In addition, that presentation also resulted in a request from Eaton Electrical Corp., a large manufacturer of residential and industrial electrical equipment, to use information from the presentation and the journal article for their publications and presentations. Furthermore, CapSchell,

Inc, a company engaged in training of Navy personnel, acknowledged the Construction Program work as changing the electrical safety culture based upon the presentation of a factual understanding of the hazards.

Contact with wiring and electrical components
The training director of Shermco Industries,[1] a member of the National Fire Protection Association (NFPA) 70E Committee, published an article in 2004 in *National Electrical Testing Association World* that reported extensively on a 2003 presentation by Construction Program researchers at the 11th Annual IEEE-IAS Electrical Safety Workshop [White 2004]. He explained Construction Program findings about the hazard of arc-flashes and a six step process to protect workers from arc-flash burn incidents. Our work was acknowledged to be the first to differentiate electric shock from electric burn injuries. Moreover, the Construction Program study was credited with highlighting the most significant cause of electrocutions—contact with overhead power lines [Floyd 2004a].

In 2004, the NFPA 70E Committee convened a NFPA/IEEE Joint Work Group Research and Testing Planning Committee to study the thermal effects of electric arc and other hazards such as pressure waves and acoustical effects of electrical faults. The committee[1] is responsible for establishing the requirements and guidelines for testing for 208-volt equipment, accuracy of the data, whether inherently-safe equipment reduces the hazard, effects of the lack of maintenance on many power systems, how people interact with equipment, effects of being in the plasma, and other hazards such as blast and projectiles.

An eight-hour training course involving lockout/tagout and a live work permitting system was developed and administered to construction electrical supervisors at an Illinois company. Partners in this training included the IBEW/NECA National Joint Apprenticeship Training Committee (NJATC) and EII Holding Company. The text for the course was “Protection from Electric Shock and Arc Flash” [McCann, 2003] based on NFPA 70E Electrical *Safety Requirements for Employee Workplaces*.

EGIZII Electric implemented a comprehensive energized electrical work program modeled after that found in NFPA 70 E, complete with a permitting system and customer sign off. This improved training was prompted by participation in an energized electrical work seminar conducted by the Construction Center. EGIZII Electric is committed to keeping its employees safe, and feels that it is better informed on the topic of energized electrical work thanks to the seminar according to Kevin Miner, VP/Safety, EGIZII Electric, Inc.

DuPont Corporation requested and received a master copy of the training DVD “Arc flash Awareness” to reproduce at its own expense for internal training [NIOSH 2006]. The IEEE exhibited the video to 400 electrical safety executives, managers, and engineers at its Petroleum and Chemical Industries Committee’s (PCIC) Electrical Safety Workshop in Calgary, Alberta, Canada, 2007. The ESFI

is translating the training and is reproducing 1,250 copies in Spanish and 200 in Portuguese (for training in Brazil). IBEW Local Union No. 5 has requested 3000 copies to distribute as training material. MSHA produced copies at its National Mine Safety and Health Academy for distribution through its educational catalog and through its new mobile electrical safety education units.

The Electrical Safety Curriculum is made available to their members via web link by the National Electrical Contractors Association (NECA – see http://www.necanet.org/safety/) and the Independent Electrical Contractors (IEC - see http://www.ieci.org/index.mv?screen=230&xsub=2)

F) External Factors

One impediment to the widespread adoption of OHPL proximity warning alarm technology is the lack of final OSHA language that allows their use in lieu of other power line proximity or contact warning means. OSHA has now proposed such language. The cost of these systems (about $4000/crane) may inhibit their adoption by smaller contractors. Perceived performance limitations of electric field-based OHPL proximity warning alarms have also impeded their widespread acceptance.

G) What's Ahead?

OHPL
A Workplace Solutions document will be published in 2007 entitled: "Preventing Electrocutions from Aluminum Ladders Contacting Overhead Power Lines." This document will also be translated into Spanish.

A test report will be issued that characterizes the performance of commercially available OHPL proximity warning alarms. That report is expected to contribute to the knowledge base necessary to produce a national standard that lays out objective performance criteria for these devices. A study will be conducted to investigate alternate approaches to OHPL proximity determination that do not depend on electric field detection.

Contact with wiring and electrical components
A publication that describes the impact of the electrical hazards training manual (see above) on student knowledge gains and safety attitudes is now being written for dissemination as a journal article. It will include recommendations regarding the effectiveness of the electrical safety curriculum on student knowledge gains and safety attitudes and information regarding when safety training videos would be most effective—either prior to or subsequent to administration of a safety training program.

Electrical safety was selected as one of seven NIOSH draft strategic goal topics, and was also selected as a top injury problem by the NORA Construction Sector

Council. Thus, this topic will be undergoing additional strategic planning regarding efforts needed over the decade.

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Appendix 1.2

Outputs

OHPL

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NIOSH [2003] Hispanic Painter Electrocuted When The Metal Ladder He Was Repositioning Contacted Overhead Powerline-North Carolina, FACE 2003-10

NIOSH [2003] Hispanic Painter Electrocuted When The Ladder He Was Carrying Contacted a 13,200 Volt Overhead Powerline—North Carolina, FACE 2003-08

Conference papers and presentations:
Cawley-JC; Homce-GT [2005] Electrical Safety for Water Well Drillers;, NIOSH; An invited, 90-minute workshop held twice at the South Atlantic Water Well Driller's Jubilee, Myrtle Beach, SC, July 30-31, 2005

Cawley-JC; Homce-GT [2004] Electrical Safety for Water Well Drillers;, NIOSH; An invited 90-minute workshop held at the National Ground Water Association annual meeting in Las Vegas, NV, December 12, 2004

Cawley-JC; Homce-GT, [2002] Presentation to the OSHA Negotiated Rulemaking Working Group (Jim Ahern, Chair.) regarding overhead power line hazards; NIOSH, Washington D.C., Oct. 22, 2002

Additional Outputs:
Sacks-HK; Yenchek-MR; Homce-GT; Cawley-JC [2003] "Alarm System for Detecting Hazards Due to Power Transmission Lines", U.S Patent #6,600,426. July 29, 2003.

Other Hazards (including outputs about all hazards including OHPL)

Journal Articles:
Cawley-JC; Homce-GT [2003]. Occupational Electrical Injuries in the United States, 1992-1998, and Recommendations for Safety Research, J Safety Research Aug; 34(3):241-248

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McCann M. [2001]. “Causes of Electrical Injuries and Deaths Among Construction Workers”. Poster presentation at George Washington University Medical Center Research Day. Washington, DC, April 19.

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Sub goal 1.3 Struck-by incidents involving vehicles, equipment, and tools

A) Issue

Struck by events encompass several injury scenarios. "Struck by object" is a sub-category within the larger BLS category for "Contact with Objects and Equipment". It includes injuries associated with falling and flying objects. In addition, "Pedestrian struck by vehicle or mobile equipment" is a subcategory of the larger BLS category for "Transportation accidents". Both are important and involve separate risk factors and interventions as described further below.

Pedestrian struck by vehicles and equipment
For the eight-year period between 1995 and 2002, 802 workers in the construction industry were fatally injured when struck by a vehicle or mobile equipment [BLS 2007]. Almost half of these fatalities (387) occurred in the highway and street construction sector. Precautions and interventions such as jersey barriers and traffic control plans exist for protecting road construction workers from being struck by passenger vehicles. However, Construction Program researchers found that road construction workers were as likely to be struck by a construction vehicle (48% of cases) as by a passing motorist. (48% of cases) [Pratt et al. 2001] Several factors were identified as contributing issues:

- Lack of knowledge on specific risk factors
- Insufficient adaptation of intervention technologies used in other industries
- Lack of scientific evaluation for existing and newly developed intervention approaches
- Inadequate guidelines, particularly for controlling vehicle and worker movements inside the work zone

The NIOSH Construction Program, partnering with the NIOSH Traumatic Injury Program and industry, labor, and government stakeholders, is working to develop and eventually disseminate interventions and guidelines to prevent these fatal and serious injuries.

Struck by flying object – nail guns
In the last two decades, hand operated power tools have revolutionized construction techniques and increased building rates significantly, but these tools have created a new set of workplace hazards that are often not well characterized. In a study that ended in 2002, Construction Center researchers concluded that workers in wood frame construction were at high risk for serious injury from one of the most ubiquitous of hand tools—the nail gun. During 2001-2005, approximately 22,200 workers per year were treated in U.S. hospital emergency departments for nail-gun related injuries [CDC 2007].

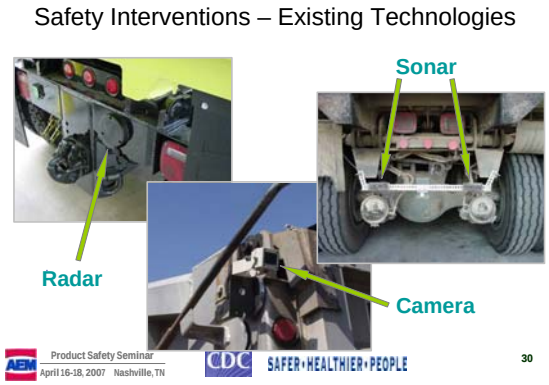
B) Activities

Pedestrian struck by vehicles and equipment

To characterize work zone safety issues, Construction Program researchers reviewed scientific literature, analyzed data from the BLS, and reviewed investigations conducted by the FACE Program. A key issue, fatalities and injuries due to vehicles and equipment, was identified. In 1998, the Program sponsored a workshop to obtain input on prevention strategies. The workshop was attended by representatives of government, labor, industry, academia, and state departments of transportation.

In 1999, the Construction Program added highway and street construction work zone fatalities as a specific target for investigations by the FACE Program. Since then, 53 highway and street construction FACE investigations have been conducted.

In 2000, Construction Program researchers, in cooperation with the Washington State Department of Transportation, began evaluating interventions that provide construction equipment operators with the ability to monitor the blind areas around the equipment they are operating. This type of intervention is often referred to as a proximity warning system (PWS). The objective of this effort was to determine which systems were most effective and reliable in monitoring blind areas. We evaluated the effectiveness and reliability of a PWS called the Hazardous Area Signaling and Ranging Device (HASARD). The HASARD system was originally developed by Mining Program researchers for the mining industry.



The Construction Program launched an effort in 2002 to evaluate selected prevention measures designed to protect workers from being struck by construction vehicles and equipment. Interventions being evaluated include several PWS devices and an administrative approach called an internal traffic control plan (ITCP). ITCPs are designed to assist in controlling construction vehicle and worker movements inside the work zone.

They apply the “Traffic Control Plan” concept used to protect road construction workers from passenger vehicles to the construction vehicle and pedestrian routes used inside the work zone itself.

A third complementary intervention is the development of blind area diagrams for construction vehicles. These diagrams are unique to each type of vehicle and can be used to raise awareness of blind areas for construction vehicle drivers, construction workers on foot, and vehicle manufacturers.

NIOSH also joined a “Roadway Workzone Safety and Health Coalition” in November of 2003 to provide a Research to Practice vehicle to disseminate findings via key partners including:

- American Road and Transportation Builders Association (ARTBA)
- International Union of Operating Engineers (IUOE)
- Laborers' International Union of North America (LIUNA)
- National Asphalt Pavement Association (NAPA)
- Occupational Safety and Health Administration (OSHA)

In 2005, Construction Center researchers initiated an effort to address safety issues for work zone construction that occurs at night. Two components of the research that relate to vehicle and equipment struck-by incidents are: 1) visibility of workers, which includes site lighting strategies, high-visibility garment selection, 2) PWS effectiveness at night, and 3) traffic control.

The “Roadway Workzone Safety and Health Partners agreement was” renewed in January of 2007 with the Associated General Contractors (AGC) joining the group.

Nail guns

To identify and characterize injury hazards among residential construction workers, Construction Center researchers conducted active injury surveillance with follow up investigations among unionized drywall and residential carpenters in Missouri. Pneumatic nail gun-related injuries were identified as common among these workers, particularly from high speed bounce nailing. We found that 65-69% of nail-gun injuries could likely be prevented by a simple engineering change to the trigger mechanism. Most carpenters used a contact-trip trigger which required the trigger to be manually depressed or locked in the on position and the nose of the nail gun to be depressed simultaneously. Thus, each time the nose contacted or bounced along a surface a nail was fired. Construction Center staff are promoting a safer trigger mechanism (the nail gun nose must be depressed and then the manual trigger depressed before a nail can fire) and working with the International Staple, Nail, and Tool Associations to improve the voluntary standard promoting this safer trigger mechanism. We intend to monitor diffusion and usage of the safer sequential-trip trigger into residential construction.

We are also working with the carpenters' union apprenticeship program to improve training in safe nail gun usage. As a result of the recent media attention, they are assisting with a fledgling effort in one state to introduce proper nail gun safety into the high school industrial arts program.

To supplement these findings and look at national trends, Construction Center and Program researchers conducted a review of emergency department (ED) treated nail gun-related injuries through NIOSH's occupational injury supplement to the National Electronic Injury Surveillance System (NEISS-Work). In 2007, we identified workers as having approximately 20,000 or more nail-gun injuries per year from 1998-2005 with no obvious improvement over the years. In examining similar data for ED-treated injuries among consumers, we identified a 200% increase in nail-gun injuries since the early 1990's with current annual estimates of about 15,000 injuries [CDC, 2007].

C) Outputs and transfer

(See Appendix 1.3 for full list of outputs related to this sub goal topic)

Pedestrian struck by vehicles and equipment
During efforts to evaluate the effectiveness and reliability of PWS devices, Construction Program researchers developed a specialized prototype of the HASARD system. This prototype system, specifically designed for use on road construction dump trucks, was presented to manufacturing companies for further development.

In developing methods to evaluate work zone safety interventions, the Construction Program produced five reports for use by other program researchers. They provide information on blind area diagrams and ITCP development. These documents are distributed externally upon request.

Construction Program researchers delivered at least 26 presentations at professional meetings to solicit participation in the effort to evaluate work zone safety interventions on active road construction sites and to provide information about ongoing research relevant to the highway and street construction industry sector. Attendees were generally safety professionals and construction association members.

Construction Program staff authored a NIOSH document, Building Safer Highway Work Zones: Measures to Prevent Worker Injuries from Vehicles and Equipment, that was based on stakeholder input received during the 1998 workshop sponsored by the Construction Program [Pratt et al. 2001]. The document serves as an education and training tool for contractors, contracting agencies, policy makers, manufacturers, law enforcement, and the research community by providing information on specific measures that can be used to reduce vehicle- and equipment-related injuries in highway work zones. Building Safer Highway

Work Zones has been disseminated through targeted mailings, conference and exhibition handouts, and downloads from the NIOSH web site. From four separate printings, approximately 21,000 copies have been distributed. It has been redistributed by OSHA offices in Washington D.C. and Puerto Rico, the Laborers' International Union of North America, the American Road and Transportation Builders Association (ARTBA), and the Washington State Department of Labor and Industries.

The 53 highway work zone FACE investigation reports, which serve as training resources for construction contractors, are accessible on the NIOSH web site at http://www.cdc.gov/niosh/injury/traumazoneface.html. Forty-one of these reports involve a worker being struck by a vehicle or equipment. Copies of the reports are also provided to OSHA.

To educate contractors, manufacturers, and the research community on PWS evaluation results, a Construction Program researcher authored a NIOSH document, "Evaluation of Systems to Monitor Blind Areas behind Trucks Used in Road Construction and Maintenance: Phase 1" [Ruff 2003]. The PWS evaluations results were also disseminated through four presentations at professional meetings and in one peer-reviewed journal article.

A Construction program researcher co-authored with a Roadway Workzone coalition partner a guide for contractors and workers titled "Internal Traffic Control Plans" in 2003.

Construction Center researchers authored two theses describing safety issues related to nighttime work zone construction. One thesis presents safety perceptions of workers and the effect of safety management planning [Spadaccini 2005] and the other presents traffic control issues [Burgess 2006].

Nail guns

Construction Center researchers published a series of nail gun-related injury articles in peer-reviewed academic journals and trade journals. Three peer-reviewed articles on nail guns characterized injuries among residential carpenters. [Dement et al. 2003, Lipscomb et al. 2003, Lipscomb et al. 2006]. In addition, results of the nail gun study of injuries treated in emergency departments was published in Morbidity Mortality Weekly Report [CDC, 2007]. Additional one minute and four minute podcasts involving an interview with the Construction Center researcher were also developed to describe the study results.

Among the more than dozen professional presentations by Construction Center researchers since 2000, the benefits of active injury surveillance and the prevention of nail gun injuries have been consistent threads. However, for workers, the dissemination of the study results and safety information through the Carpenters District Council newsletter and web site and presentations at local

union meetings by journeyman investigators participating in the study were likely more effective at transferring information.

The consumer and worker nail gun injury report by the Construction Center and Program researchers struck a cord with the national media. Newspaper articles describing the hazard to consumers and workers were disseminated in most states and several foreign countries. Good Morning America had a brief segment on nail gun injuries. Although the focus of many of the articles was on consumer injuries, the benefits of more wide spread recognition of nail guns as a hazardous tool and the availability of an engineering solution will likely have positive carryovers to worker safety.

D) Intermediate and end outcomes

Pedestrian struck by vehicles and equipment
Construction Program work zone safety research results, including that from PWS evaluations and contractor reports on blind area diagrams, were requested by two PWS device manufacturers, Tag Safety Systems and Gamma Services Int., for product development and marketing. These manufacturers incorporated specifications and recommendations from the evaluation results to make product improvements and to develop new systems. Two other manufacturing companies, Geosteering and Frederick Energy Products, used the HASARD system license in developing their own PWS devices.

In March 2004, The Bureau of National Affairs (BNA) published an article in its Daily Report for Executives that featured the ongoing Construction Program research efforts to evaluate injury prevention measures on active road construction sites [Scovron 2004]. The article encouraged construction companies who were interested in participating to contact Construction Program researchers.

The National Asphalt Pavement Association published two separate articles [Jay 2005; MacDonald 2007] in Hot Mix Asphalt Technology to describe ongoing Construction Program research efforts to evaluate injury prevention measures on active road construction sites. The 2005 article discussed the interventions being evaluated, data collection methods, and road construction site criteria. This article encouraged construction companies who were interested in participating to contact Construction Program researchers. The 2007 article focused entirely on ITCPs, one of the interventions being evaluated.

ARTBA and the National Safety Council (NSC) consulted with Construction Program researchers in developing an OSHA 10-hour training course specifically for the road construction industry. Key measures from Building Safer Highway Work Zones were incorporated in the course training materials. This OSHA 10-hour course is provided to member construction companies for NSC and ARTBA, and is also a core component of the road construction safety training program for

the Associated General Contractors of Vermont's Northeast Regional Safety Academy.

The Laborers' Health and Safety Fund of North America (LHSFNA) incorporated the entire Injury Prevention Measures and Glossary sections of Building Safer Highway Work Zones in the appendix and glossary sections of their "Highway Workzone Safety Manual 2003" [LHSFNA 2003]. Other organizations have used the document to develop safety training videos (J. J. Keller and Associates) and to develop safety training programs (Texas Engineering Extension Service, LHSFNA, Washington State Department of Labor and Industries, and Wayne State University).

In June 2000, the *Engineering News Record* published an article featuring the pending release of the *Building Safer Highway Work Zones* document [Krizan 2000]. The article noted that the document was much anticipated and included several of the injury prevention measures from the document.

Results from the Construction Program research on work zone safety have been requested and used by individual construction companies for education and training purposes. One company used the contractor reports on blind area diagrams during a company-wide safety stand down.1 Other companies have incorporated safety measures and FACE case examples into tool-box safety talks.

Materials developed through the nighttime construction research conducted by the Construction Center were incorporated into Purdue University curriculum for a core course in construction engineering and management. This course has an enrollment of approximately 150 students per year.

In setting standards and establishing guidelines, *Building Safer Highway Work Zones* has been used by organizations to:

- Provide risk management recommendations to clients (St. Paul and the CNA insurance companies)
- Support development of contract language to require contractors to use high-visibility clothing during disaster clean-up (Federal Emergency Management Agency)
- Guide strategic planning for transportation centers (Cleveland State University)
- Incorporate injury prevention measures into a best practices guide (The Dallas Area Road Construction Work Zone Task Force)

Results from Construction Program research on work zone safety have been requested by organizations that affect standards and guidelines. Washington State Department of Labor and Industries used the contractor reports on blind area diagrams and ITCP development in preparing recommendations for internal

traffic control. Washington State Department of Transportation used PWS evaluation results to select appropriate technologies for departmental dump trucks. Construction Program researchers also provided input into two separate standards: 1) the International Organization for Standardization (ISO) Standard 16001 (Earth Moving Machinery – Hazard Detection Systems and Visual Aids – Performance Requirements and Tests), which is in the final international approval stage and 2) the American National Standards Institute (ANSI) A10.47 Standard (Highway Construction Safety Practices – Work Zone Safety for Highway Construction), which is in draft stage scheduled for a July 2007 submission.

In 2007, OSHA requested approval to reprint and distribute the "Internal Traffic Control Plan" guide co-authored by a Construction Program researcher.

Nail guns
Beginning in May 2003, the International Staple, Nail, and Tool Association adopted a new voluntary standard calling for shipment of the tools with a safer sequential-trip trigger (i.e., the nail-gun nose must be depressed and then the manual trigger depressed before a nail can fire).

E) External Factors

Pedestrian struck by vehicles and equipment
Several factors challenge Construction Program research in highway and street work zone safety, including the following:

- Regulation for safe work practices in work zones falls under the jurisdiction of both the Federal Highway Administration and OSHA
- The industry is fractured by relatively small family businesses located in disparate localities
- The work environment is mobile with constantly changing variables (e.g., weather, construction phase)
- The industry base is changing with corporate consolidation, foreign investments, adoption of night work, and an increase in the number of non-English-speaking workers
- Field-based research is resource intensive requiring significant travel, personnel, and equipment expense

Construction Program researchers have been relatively successful in meeting these challenges by partnering through alliance memberships that involve government, industry, and labor representation.

Nail guns
Despite the availability of the safer trigger mechanism, Construction Center researchers still find that the contact-trip trigger is commonly used in construction to facilitate speedier nailing.

Several factors challenge Construction Program research in safer tool design and use, including the following:

- Most construction tools, including nail guns, do not have regulated design features or usage restrictions. Instead, most tool manufacturing is based on voluntary standards without third party certification.
- The industry, particularly residential construction, is dominated by relatively small, non-unionized businesses with a highly mobile workforce. Training and safety infrastructure tend to be lacking in this population and uniformly disseminating safety information is nearly impossible.
- Sales and hours-of-use data for nail guns or other tools are generally not available.
- General injury surveillance programs do not collect sufficient details to ascribe injuries to specific tool models or brands, modes of usage, or situational characteristics.
- Active injury surveillance with follow up investigations successfully meets many of the detailed injury etiology needs, but remains expensive and complex to set up.

F) What's Ahead?

Vehicles and equipment

The Construction Program continues work zone safety surveillance activities by retaining the topic as a target for FACE investigations and providing for periodic analysis of existing data. Construction Center researchers continue with surveillance efforts to better understand factors related to safety during nighttime construction in work zones. Results from these surveillance activities will be used to identify new risk factors, identify injury prevention strategies, and guide and prioritize future research efforts.

The Construction Program is also continuing to evaluate PWS and ITCP interventions on highway construction sites. Researchers in the program are also continuing to identify, develop, adapt, and evaluate emerging technologies specifically related to PWS devices. Finally, Construction Center researchers continue to evaluate interventions related to nighttime construction safety, specifically for traffic control and visibility of workers. It is anticipated that each of these activities will result in outputs that stakeholders will use to advance highway and street construction worker safety.

Construction Program results and information from the PWS and ITCP intervention research will be published for education and training purposes in peer-reviewed journals and will be packaged for targeted dissemination to stakeholders in the highway and street construction industry. Construction Program researchers will also provide products to partners through continued involvement in the OSHA/NIOSH Roadway Work Zone Safety and Health

Alliance. It is anticipated that the Alliance partners will repackage the Construction Program outputs as training tools and will invest in additional dissemination strategies.

Nail guns

A new pilot study is underway to add standard industry identification to the occupational ED injury data collected by NEISS.

NIOSH developed draft strategic goals in 2005 for reducing fatal and serious injuries caused by roadway construction workers being run over by vehicles and equipment. The draft goal and intermediate steps was intended to achieve an ambitious 40% reduction in the number of fatalities and injuries over a ten year period. In addition, the NORA Construction Sector Council has also identified struck by injury events as a top problem. In addition to focusing on struck-bys associated with roadway construction vehicles and equipment, the group is interested in clarifying risk factors and identifying interventions for the several other types of struck-by injuries.

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APPENDIX 1.3

Vehicles and equipment
Journal articles

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Sub goal 1.4 Confined Space, Excavations, and Trenching

A) Issue

Confined space and excavation hazards are important risks for construction workers. Confined spaces include storage tanks, process vessels, pits, boilers, ventilation and exhaust ducts, sewers, tunnels, underground utility vaults, and pipelines. With excavations and trenching, cave-ins pose the greatest risk to workers. Other potential hazards inherent to confined space excavations include falls, falling loads, hazardous atmospheres, and incidents involving mobile equipment.

During 1992 – 2001, CFOI data identified 542 fatalities associated with trenching and excavation [MMWR, 2004]. Trench cave-ins accounted for 76% of the deaths. OSHA's standard (Subpart P of 29 CFR 1926) is designed to prevent trenching and excavation related injuries and deaths. Employers, employees, safety professionals, regulators, and researchers need a better understanding of the factors that contribute to these injuries and deaths. An evaluation of CFOI data for the years 1997-2001 reported 89 construction fatalities associated with confined spaces [Meyer, 2003]

NIOSH issued a recommended standard for confined spaces in 1979, an Alert in 1986, and a safety guide for confined spaces in 1987. NIOSH developed draft construction safety standards for excavation in 1983 and an Alert in 1985. NIOSH provided technical input to OSHA for the revision of their excavation standard in 1989. NIOSH also provided input in 1995 on OSHA's general industry standard for confined spaces, but there is no current construction industry proposal on confined spaces.

B) Activities

Construction Programs have used surveillance data from a variety of sources to identify activities, trades, and risk factors associated with fatalities and injuries in confined spaces and excavations. Those sources include the FACE fatality investigation program, CFOI, and NEISS. For example, we used emergency room data to evaluate fatal and non-fatal injuries from vessels under air pressure in construction [Welch, et al. 1999]. Our researchers have also examined OSHA fatality data for toxic inhalation fatalities among construction workers and found that the majority occurred in confined spaces [Dorevitch, et al. 2002]. The Construction Program provides support for ongoing NIOSH efforts to develop and update "Immediately Dangerous to Life or Health" (IDLH) values and a pocket guide to chemical hazards, which are products commonly used for planning confined space entries.

From 2001 to 2003, Construction Program investigators conducted the “Safety in Trenching Operations” project, which addressed the “how” and “why” of fatalities that occur in trenching operations and what measures could be adapted to prevent them. We did an analysis of OSHA, BLS, and NIOSH fatality data from trenching operations. Two hundred ninety six fatality reports were analyzed based on two different incident causation models. We were able to correlate causes to identify circumstances that led to fatal incidents [Arboleda and Abraham 2004].

The Construction Program has undertaken a number of safety interventions for excavation and trenching. For example, we supported research to examine technological interventions using tele-operation of mechanical devices to dig trenches and install pipe [Li and Bernold 2005]. We also conducted the Trench Box Safety project which examined the extent of trench box use and work practices related to their use. To do that, we sent a survey to about 1000 members of a Utility Contractors Association [Hinze, 2005]. Another researcher evaluated the impact of the OSHA Trench and Excavation Standard on fatal injuries in the construction industry by comparing fatal injuries for five year periods before and after the standard went into effect in 1989. The study found a twofold decline in the rate of fatal injury from trench cave-ins in the construction industry for five-year period before and after the 1989 revision of the Excavation Standard. From 1984 to 1989, the rate was 13.5 trench cave-in deaths per million workers per year, and from 1992 to 1995, the rate was 6.8 per million workers per year. [Suruda et al. 2002]

The OSHA trenching standard is technical and includes engineering tables and diagrams that make it less accessible to contractors and construction workers. Nevertheless, most stakeholders think that if the standard were followed, most trenching operation fatal injuries would be prevented. Construction Program staff partnered with a large construction equipment rental company to gain access to equipment and sites for development of a CD-based training module to raise awareness of trenching hazards and to communicate the key features of the OSHA trenching regulation. The CD includes text, photographs and diagrams, animation, and video clips featuring construction and rescue personnel. The program worked with an OSHA Advisory Committee for Construction Safety and Health (ACCSH) trenching workgroup to finalize the CD product.

An additional project was undertaken to evaluate the CD. The evaluation used a multi-method approach to gather feedback from decision-makers, trainers/consultants, and workers in the construction industry. This information provided feedback for improving the design, content and delivery of the training.

The focus groups yielded insights about safety culture in the construction industry. The results will inform production of an improved, better-targeted version of the training CD and publications about construction safety culture.

Center researchers, collaborating with State Health Department researchers in California, interviewed excavation industry stakeholders about barriers to safe trench work and suggestions for improving safety. Interviews included trench safety training providers, trade association and union representatives, safety experts and state enforcement staff. The study resulted in several recommended prevention strategies, such as improved enforcement targeting, partnerships with fire and rescue personnel to increase awareness and enforcement referrals, increased public awareness, disseminate tailgate and training materials, specify trench protective systems in public contracts for trench work, and promote mentoring of smaller firms to share safety expertise.

C) Outputs and Transfer

(For a complete listing of outputs, please refer to Appendix 1.4)

Construction Program staff delivered three presentations at construction safety meetings to report findings, and prepared 28 publications/products, including two journal articles, one Alert, one book chapter, one thesis, 20 FACE reports, and the monograph entitled “Worker Deaths in Confined Spaces”. A report titled: “Occupational Fatalities During Trenching and Excavation Work --- United States, 1992—2001” was published in the Worker Memorial Day edition of Morbidity Mortality Weekly Report (MMWR) as a mechanism to raise awareness about this issue among state and local health department personnel. [MMWR 2004].

The Program prepared seven publications on innovative excavation technologies, including five journal articles. Results of the trench box study were published in the Journal of Construction Engineering and Management [Hinze, 2005]. The study of the effectiveness of the OSHA trenching standard was

published in the Journal of Occupational and Environmental Medicine [Suruda et al, 2002]. The Center study "Strategies to Prevent Trenching-Related Injuries and Deaths" was published by the Center in 2006 [Plog et al. 2006] The trench safety CD has been disseminated to over 4000 users and a web version was created for linkage via the NIOSH Trenching and Excavation safety topic page http://www.cdc.gov/niosh/topics/trenching/. Program and Center researchers co-presented on a panel discussion on trench safety issues held at the 2005 American Industrial Hygiene Association Conference.

Materials developed for the Safety in Trenching Operations project were incorporated into three courses in the Construction Engineering Curriculum at Purdue University. Those courses enroll about 250 students per year. In addition, undergraduate and graduate research assistants who were employed on this grant, used materials from the study on their field internship assignments and their post-school jobs.

Construction Center trainers have provided confined space training since 1994, and have trained employees in 31 states. More than 438 courses have been delivered, training more than 6,700 students. These courses use Construction Program-supported materials such as the NIOSH Pocket Guide and IDLH levels.

Construction Program researchers created and released the "Trench Safety Awareness Training- Trench Protective Systems: Use and Management" software-based training module. The CD was publicized within the OSHA Advisory Committee on Construction Safety and Health (ACCSH) trench workgroup. Most of the copies printed for dissemination were provided to OSHA (See Intermediate and End outcomes section). In addition, a web-mounted version of the training exercise was also developed and is located at: http://www.cdc.gov/niosh/docs/2006-133D/ for download by users.

In coordination with the NIOSH Traumatic Injuries program, we prepared and submitted comments to OSHA in 2002 for their Regulatory Flexibility Act Review of the Excavation Standard.

D) Intermediate and End Outcomes

OSHA used the Suruda article in their regulatory review analysis.

OSHA originally requested 500 copies of the trench safety CD to include in a mailing to the largest construction /excavation/trenching companies in the United States. A trenching safety pocket card and a letter alerting them to the hazards of trenching was also included. After positive feedback, the OSHA Construction Directorate requested 5000 copies, stating that "We cannot keep them in stock...the Trench Initiative Package is our #1 distribution item here in the Directorate of Construction."

Using CDs and the Internet, OSHA and NIOSH have distributed over 8000 copies of the CD. OSHA has used the trench safety CD with construction stakeholders and OSHA staff and compliance personnel. Construction Program staff were included in the OSHA "Trench Initiative Team" that was awarded the U.S. Department of Labor Secretary's Exceptional Achievement Award in recognition of delivering a multi-disciplinary approach to reach an estimated 300,000 construction industry personnel and challenging the industry to adopt a trench safety culture.

The equipment rental firm that partnered with the Construction Program to develop the CD has customized it further and is using it to train their sales force on trench safety and related equipment.

A California OSHA program used the Center report on "Strategies to Prevent Trenching-Related Injuries and Deaths" to develop a training course for contractors in California.

Groups such as the Associated General Contractors include a link to the NIOSH Trenching and Excavation topic page on their safety websites.

E) External Factors

Even with work environments as dangerous as confined spaces, trenches, and excavations, employers often fail to train workers to comply with the existing OSHA regulations. In addition, the industry has a transient and decentralized workforce. Workers are often faced with making difficult decisions about work practices on their own. This is especially true for those who work for small contractors.

F) What's Ahead?

Construction Program supported researchers that assisted in the design of the original CD produced through the Assessing the Risks of Injury in Trenching and Excavation in the United States have modified it and are beginning an effort to train 20,000-40,000 competent persons per year.

Based upon the evaluation findings, the trench safety CD will be improved using a multimedia design company. We will study channels for CD distribution, especially targeting small businesses. Through the equipment rental company partner, we hope to reach as many as 20,000 of those small businesses.

There is interest among stakeholders in using excavation as an issue to learn more about implementation issues in construction. This is because the OSHA trenching standard approach is viewed as effective and the remaining obstacles to prevention appear to be related to raising awareness and getting contractors to use these existing precautions. There is interest in continuing efforts to

explore other approaches by OSHA's ACCSH trenching workgroup and by members of the NORA Construction Sector Council.

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Appendix 1.4

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Nebraska [1997] Backhoe Bucket Crushes Worker in Trench. Report No. 97NE041

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Construction Center researchers
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Hazard Alert: Safe Work in Trenches

Hazard alerts reprinted: Most recent request – Jeff Ditz, semcosh.org, SE Michigan Coalition on Occupational Safety and Health; CPWR granted permission to reproduce trenching hazard alert

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Sub goal 1.5: Construction Vehicle Rollovers

A) Issue

Heavy equipment is common to many construction operations and a Construction Program study of machines using NTOF surveillance system data for the years from 1980 through 1989 indicated that the machines most frequently associated with construction industry fatalities were cranes (17%), excavators (15%), tractors (15%), loaders (9%), and pavers (7%). One of the most common events (18%) associated with fatalities was vehicle overturns [Prattet al. 1995].

Another Construction Program study of NTOF surveillance system data identified machinery-related incidents as the fourth leading cause of traumatic occupational fatalities in the construction industry between 1980 and 1992, resulting in 1,901 deaths (2.13 deaths per 100,000 workers). Again, overturns were found to be common [Pratt et al. 1997]. Rollovers of heavy construction equipment usually occur when they are driven on slopes or steep roads, or when they are loaded onto or unloaded from the flatbed trucks used to transport them. The term “tip-over” is more commonly used to describe crane and personnel lift overturns. Tip-overs are related to crane or lift instability under load or improper set up rather than operation on sloped surfaces.

Analyses of rollover incidents and Rollover Protective Structures (ROPS) found that ROPS generally reduced the number of injuries and deaths when they are present on construction machines. [Woodward 1985] Studies also indicate that the severity of rollovers vary widely among different types of machines, that quality control during ROPS fabrication is important, and that the chances of surviving a rollover are enhanced substantially by wearing a seat belt [Woodward 1985].

In 1972, OSHA promulgated a standard that required ROPS on many types of vehicles used in construction work [OSHA 1972]. In the standard specific requirements for ROPS on compactors and rubber-tired skid-steer equipment

were not included. Thus, ROPS are not standard equipment on compactors used at construction worksites. FACE investigations over the years have documented serious injuries and deaths resulting from overturns and runaways of compactors, but awareness is low and the problem has received scant attention [Myers 2004].

B) Activities

The Construction Program has used existing surveillance resources and programs to identify risk factors associated with construction vehicle overturns and to develop prevention measures to address them. Such measures include engineering interventions targeted to equipment manufacturers and work practice interventions targeted to construction vehicle users.

Two of the program's studies are described above, and we have completed several other investigations.

A Construction Program review of CFOI data identified 282 deaths associated with road grading and surfacing machinery during 1992-2001 [NIOSH 2004b]. At least 70 of these deaths involved roller/compactors. Review of these data narratives and of NIOSH FACE case studies suggests two common causes of injury: (1) machine rollovers and (2) incidents involving workers being struck by moving machines.

A Program study of deaths that occurred on construction excavation sites from 1992 through 2002 [McCann, 2006] identified 57 rollover deaths (23%) out of a total of 253 vehicle-related deaths. Vehicles driven over an embankment or slope caused 21 (37%) of the 57 rollover deaths; and 16 (28%) of the deaths occurred while the vehicle was being loaded to or unloaded from a trailer truck or similar vehicle. In 13 of the rollover deaths (23%), the vehicle operator did not have the seatbelt fastened. In six death incidents, the operator was ejected from the vehicle and in five other death incidents, the operator struck the ROPS. The types of vehicles involved in the rollover deaths included bulldozers (18), loaders (10), backhoes or other excavating equipment (9), road grading and surfacing machines (7), tractors (6), and trucks (5).

In 1996, Construction Program investigators from the state component of NIOSH FACE program summarized surveillance data for the period from 1980 through 1995, described the results of FACE program investigations of skid-steer loader-related fatalities and made recommendations for preventing fatal incidents, including deaths related to rollovers [Parker et al. 1996]. They found that during the period from 1980 through 1992, rollovers accounted for 15 deaths (28%).

Of 1,021 U.S. workers who died from traumatic injuries in forklift-related incidents from 1980 through 1994, 225 (22%) were killed as a result of overturns [NIOSH 2001b].

A NIOSH review of the CFOI data identified 346 deaths associated with excavators or backhoe loaders from 1992 through 2000. A review of these data and of FACE cases found that rollover was a leading cause of these fatalities [Casini & Moore 2003].

On-site investigations of worker deaths involving construction vehicle rollovers were conducted by NIOSH Construction Program research team personnel starting in 1994 and continuing to the present. Investigators collected data on the agent, host, and environmental factors from the pre-event, event, and post-event phases of the fatal incident via a case series design used to facilitate descriptive analysis of the incidents. These investigations were not conducted to find fault or place blame, but to better understand the chain of events and identify all contributing factors – thus allowing the development of recommendations for preventing similar deaths. Findings from Construction Program research team investigations were frequently combined with surveillance data to identify and describe specific injury problems.

To overcome the assumption that compactors are safe because they work on level surfaces, an investigation was undertaken under a small grant from the Construction Center. A total of 58 reports from 1984 to 2002 were acquired and analyzed. Results indicated the terrain encountered by compactors is often irregular and sloped, that overturns cause serious injuries or death, and that a ROPS is effective at stopping a roll at 90 degrees. Additionally, the tasks of loading and unloading compactors onto/from trailers, and incidents in which runaway compactors headed downhill, presented risks of rollovers. When a ROPS was present, seatbelt usage would have increased the operator's chances of surviving or averting a serious injury [Myers, 2003].

A 2003 study found that collapses and tip-overs were second most frequent cause of death associated with personnel lifts, which included boom-supported and vertical (scissor) lifts and crane platforms [McMann 2003].

A Construction Center small grant (the results of which are described in the Outputs and Transfers section) was undertaken to investigate engineering safety principles including principles for preventing equipment overturns and their related injuries.

C) Outputs and Transfer

The results of the construction vehicle rollover-related investigations were disseminated by the Construction Program research team and stakeholders through a book, narrative summary reports, NIOSH Alerts, Workplace Solutions documents, technical reports, targeted mass mailings, presentations, training modules, and journal articles. In total, Construction Program researchers authored a total of 4 peer reviewed journal articles on this topic, provided 2 presentations, and developed 9 NIOSH and Center publications, as well as 48

miscellaneous documents such as FACE reports, patents, and book chapters. Details and examples are provided below:

A Construction Center small grant resulted in a book on engineering safety principles for preventing equipment overturns [MacCollum 2007]. It was published by the principal publisher for engineering texts.

In 2004, the Construction Center issued a Hazard Alert for Operating Heavy Equipment that was available to construction workers both as printed pocket card, and as downloadable PDF files. The alert warned that equipment can roll over and kill operators when it is driven on a slope or when the equipment is being loaded to or unloaded from a flatbed/lowboy truck. It made a number of recommendations to prevent rollovers including that employers use only equipment with ROPS and seat belts. [CPWR 2004]. Construction Program researchers also developed and disseminated several other documents that included recommendations to prevent equipment rollovers [NIOSH 2005, NIOSH 2004b, NIOSH 2004c].

Additionally, four Construction Program research reports from the construction vehicle overturn related investigations were published and disseminated [NIOSH 2004c, NIOSH 2000, NIOSH 1999a, NIOSH 1999b]. These reports are available on the Web at: http://www.cdc.gov/niosh/face/default.html. State partners such as Wisconsin, California, and New Jersey disseminate NIOSH Construction Program research products.

A NIOSH *Workplace Solutions* document identified controls to prevent injuries when working with hydraulic excavators and backhoe loaders. These controls included not permitting hydraulic excavators or backhoes to be operated on grades steeper than those specified by the manufacturer and not removing the ROPS and using the seat belts supplied by the manufacturer [Casini & Moore 2003].

Construction Program researchers developed and disseminated a NIOSH Alert – *Preventing worker injuries and deaths from mobile crane tip-over, boom collapse, and uncontrolled hoisted loads* [NIOSH 2006]. Approximately 6,000 copies of this Alert were disseminated to crane rental establishments, steel erection companies, heavy construction companies and any others identified that would use cranes in their work. A Construction Program presentation at the 2000 National Occupational Injury Research Symposium recommended procedures for preventing fatalities related to crane overturns. Recommendations included operating within manufacturers' recommended capacities and using load monitoring instruments [Moore & Pratt 2000].

NIOSH issued an Alert in 2001 requesting assistance in preventing injuries and deaths of workers who operate or work near forklifts. The Alert recommended that seatbelts be used when available and that the operator not jump from an

overturning forklift. Operators were advised to stay with the truck, holding on firmly and leaning in the opposite direction of the overturn [NIOSH 2001a].

In 1998, NIOSH issued an Alert requesting assistance in preventing injuries and deaths from skid-steer loaders. Skid-steer loaders now come equipped with ROPS, side screens, and seat belts to protect the operator if the machine turns over [NIOSH 1998].

In 1998, NIOSH convened a workshop entitled *Preventing Vehicle- and Equipment-Related Occupational Injuries in Highway and Street Construction Work Zones*. Recommended safety measures included use of equipment with ROPS [Pratt et al. 2001].

Planned outputs include an article on compactor/roller rollovers (submitted to *Accident Analysis & Prevention*) and an article submitted to Professional Safety on the effectiveness of ROPS and seatbelts.

D) Intermediate and End Outcomes

The International Union of Operating Engineers (IUOE) and the Association of Equipment Manufacturers (AEM) presented the CWPR results to the Advisory Committee on Construction Safety and Health (ACCSH) in 2004 with a plea for action to require ROPS on compactors. ACCSH formed a ROPS work group in 2004 to recommend a standard for ROPS on compactors. Awaiting input from AEM, the group has yet to submit their recommendation to the Committee.

The Center for Research on Occupational and Environmental Toxicology in Oregon reported on the NIOSH document, *Workplace Solutions: Preventing Injuries when working with ride-on roller/compactors, restating its recommendations* [CROET 2005].

The Virginia Workers Compensation Program published an article on heavy equipment safety in 2005 [Virginia 2005]. The article used information from a Construction Program research study published as *Building Safety Highway Work Zones*. Based on data for the period from 1992 through 1998, the study reported 110 fatalities involving equipment operators, with 53% of those fatalities caused by heavy equipment including equipment overturns. The Virginia article included rules and safe work practices to prevent rollovers.

The National Association of Demolition Contractors reported on the NIOSH Alert regarding skid-steer loaders and the need for ROPS with side screens and seat belts to protect the operator if the machine turns over [NADC 2000].

In 2004, the OSHA Crane and Derrick Negotiated Rulemaking Committee reached consensus on proposed language for a revised and updated crane and

derrick safety standard for construction, which included ballast and counterweight recommendations to prevent tip-overs. [AEM, 2004].

The AEM provided a national and international mailing list of members to assist in the dissemination of two NIOSH Workplace Solutions entitled *Preventing injuries when working with ride-on roller/compactors* and *Preventing injuries when working with hydraulic excavators and backhoe loaders*. The AEM and the National Asphalt Pavement Association (NAPA) then disseminated approximately 20,000 copies of the roller/compactor publication and 11,000 copies of the hydraulic excavators and backhoe loaders publication to their memberships.

F) External Factors

Manufacturers may be motivated to support the establishment of a standard for ROPS on compactors because of the cost of tort claims from overturn-related injuries involving compactors lacking a ROPS. However, they are slow in achieving consensus regarding the wording of any recommendations.

Employers, equipment rental businesses, and used equipment dealers may have concerns about the cost of retrofitting older units or the need to replace older units with newer ones. These concerns have yet to be raised.

The Organization for Economic Cooperation and Development (OECD) is updating its international ROPS standards, and an issue in contention is whether or not to require the design of ROPS to restrict a roll to 90 degrees. The CPWR report showed that virtually all compactor overturns are limited to 90 degrees as a result of the presence of a ROPS.

In 1998, OSHA established a policy to enforce the mandatory presence of ROPS and seatbelts on compactors under the general duty clause. This raised awareness about the issue for compactor manufacturers. However, until a specific standard is put into place, some manufacturers still provide a “remove” option for ROPS on compactors at the time of sale. Moreover it is likely that older compactors without a ROPS and seatbelt will remain in service.

F) What’s Ahead?

Some targeted intermediate outcomes are an updated international standard for ROPS that includes compactors and design criteria to limit an overturn to 90 degrees and an OSHA standard requiring ROPS on compactors.

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